Pending

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
5 July 2001 (05.07.2001)

PCT

(10) International Publication Number
WO 01/48374 A2

(51) International Patent Classification[7]: F03B

(21) International Application Number: PCT/US00/35471

(22) International Filing Date:
28 December 2000 (28.12.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/173,460 29 December 1999 (29.12.1999) US

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(81) Designated States (*national*): AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *Without international search report and to be republished upon receipt of that report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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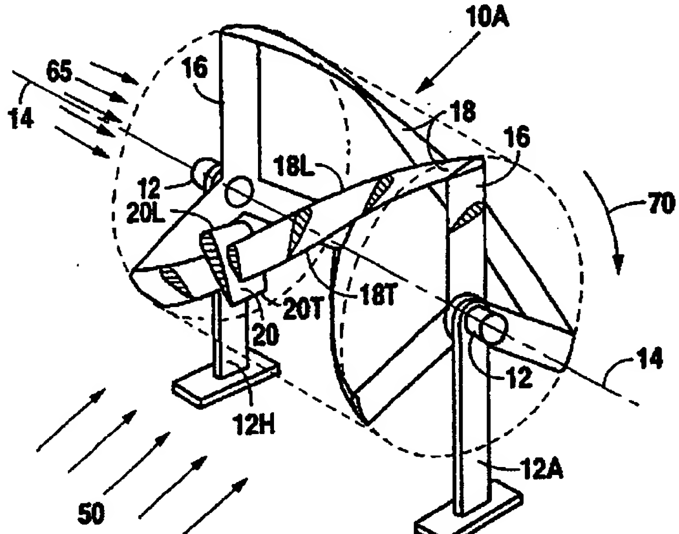

(57) Abstract: An improved reaction turbine capable of rotation in one direction under reversible fluid flow using airfoil shaped radial blades in conjunction with airfoil shaped helical blades to convert a portion of the energy from fluid flowing in an axial direction into rotational energy, thus increasing efficiency of the turbine. The conversion of axial flow into rotational energy allows the helical blades of the turbine to have a higher twist angle and the turbine itself to have a smaller length to diameter ratio, thus allowing the turbine to be more compact without compromising efficiency.

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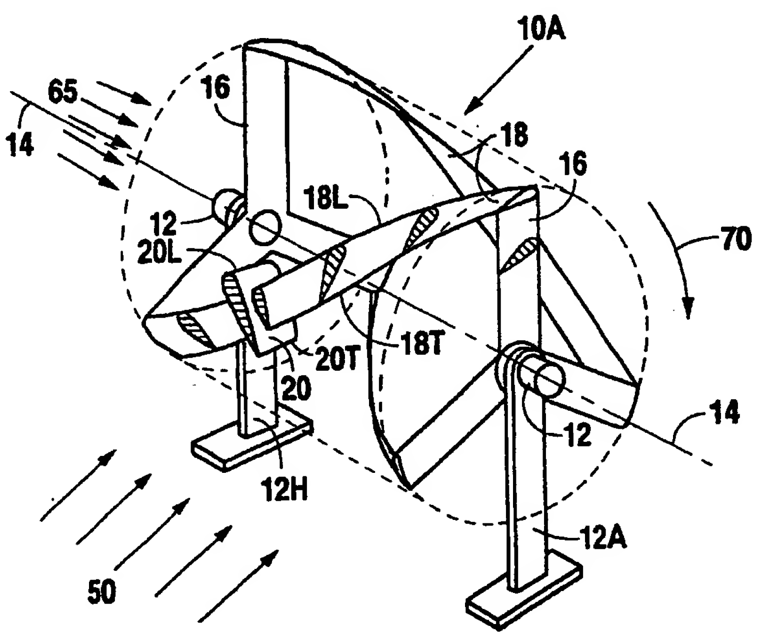

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TURBINE FOR FREE FLOWING WATER

This patent application is based upon and claims priority from a provisional application entitled "A Turbine for Free Flowing Water" having a filing date of December 29, 1999, and a serial number of 60/173,460.

BACKGROUND OF THE INVENTION

The present invention relates generally to turbines and more particularly to turbines capable of unidirectional rotation under multidirectional fluid flows for use with hydro-pneumatic, hydro, wind, or wave power systems.

A unidirectional turbine is a turbine capable of providing unidirectional rotation from bidirectional or reversible fluid flow, such as in tidal estuaries or from shifting wind directions. Generally, five basic types are known, the Wells turbine, the McCormick turbine, the Darrieus turbine, the Goldberg turbine and the Gorlov turbine.

The Wells turbine is a propeller type turbine having a series of rectangular airfoil-shaped blades arranged concentrically to extend from a rotatable shaft. Typically, the turbine is mounted within a channel that directs the fluid flow linearly along the axis of the rotatable shaft. The blades are mounted to extend radially from the rotatable shaft and rotate in a plane perpendicular to the direction of fluid flow. Regardless of the direction in which the fluid flows, the blades rotate in the direction of the leading edge of the airfoils.

The Wells turbine is capable of rapid rotation. The outer ends of its blades move substantially faster than the flowing air, causing substantial noise. The efficiency of the Wells turbine is reduced because the effective surface area of the blades is limited to the outer tips, where the linear velocity is greatest. These blades are not capable of capturing a substantial amount of the available energy in the fluid flowing closer to the shaft.

The McCormick turbine uses a series of V-shaped rotor blades mounted concentrically between two series of stator blades. The rotor blades are mounted for rotation in a plane

perpendicular to the direction of fluid flow. The stator blades direct fluid flow to the rotor blades. To achieve unidirectional rotation with bidirectional fluid flow, the outer stator blades are open to fluid flowing from one direction, while the inner stator blades are open to fluid flowing from the opposite direction.

The McCormick turbine is quieter than the Wells turbine. However, its rotational speed is too slow for direct operation of an electric generator. The McCormick turbine is complex and expensive to manufacture.

The Darrieus turbine is a reaction turbine with straight airfoil-shaped blades oriented transversely to the fluid flow and parallel to the axis of rotation. The blades may be attached to the axis by circumferential end plates, struts, or other known structures. In some variations, the blades are curved to attach to the ends of the axis. A Darrieus reaction turbine having straight rectangular blades, mounted vertically or horizontally in a rectangular channel, has been placed directly in a flowing body of water to harness hydro-power. The Darrieus turbine rotates with a strong pulsation due to acceleration of its blades passing through higher pressure zones in the fluid. This strong pulsation results in lesser efficiency for the Darrieus turbine.

The Goldberg turbine, described in U.S. Patent No. 5,405,246, the specification and drawings of which are hereby incorporated by reference, and the Gorlov turbine, described in U.S. Patent No. 5,642,894, the specification and drawings are herein incorporated by reference, make use of twisted or helical blades. The orientation of the blades used by these turbines allows torque to be produced from water or air impacting the blades in the transverse direction (direction perpendicular to the turbine's axis of rotation).

A portion of the water or air impacting the helical blades in a transverse direction is deviated in an axial direction. This axial flow places stress upon the turbine, and particularly upon the turbine bearings, causing them to require replacement in a lesser time period. Although

the Goldberg and Gorlov turbines improved upon previous designs, neither of these turbines effectively utilizes deviated flow in the axial direction.

SUMMARY OF THE INVENTION

The present invention provides an improved turbine capable of rotation in one direction under reversible fluid flow using airfoil shaped radial blades in conjunction with airfoil shaped helical blades or other twisted blades to convert a portion of the energy fluid flowing in a generally axial direction into rotational energy, thus increasing efficiency of the turbine. The conversion of deviated axial flow into rotational energy allows the helical blades of the turbine to have a higher twist angle and the turbine itself to have a smaller length to diameter ratio, thus allowing the turbine to be more compact without compromising efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a front, left side perspective view of one embodiment of the present invention.

Fig. 2 illustrates a front, left side perspective view of a portion of one embodiment of the turbine of the present invention showing transverse fluid flow deviated in a generally axial direction.

Fig. 3A illustrates a cross sectional perspective view of one embodiment of the present invention showing twisted and radial blades.

Fig. 3B illustrates a top, elevation view of one embodiment of the present invention showing deviated fluid flow upon twisted and radial blades.

Fig. 3C illustrates a front, elevation view of one embodiment of the present invention showing deviated fluid flow upon twisted and radial blades.

Fig. 4 illustrates one embodiment of the present invention showing a twisted and radial blade and accompanying shear and rotation.

Fig. 5 illustrates a side elevation view of one embodiment of the present invention showing the O-surface and angle of attack with regard to the configuration of a twisted blade.

Fig. 6 illustrates a perspective view of one embodiment of the present invention showing the design of the twisted blades and accompanying turbine appearance caused by the O-curve, B-curve, and O-surface.

Fig. 7 illustrates a side view of one embodiment showing several curvature orientations of the turbine caused by rotation of the O-curve with respect to the rotational axis.

Fig. 8 illustrates a perspective view of one embodiment of the turbine of the present invention having a barrel shaped appearance.

Fig. 9 illustrates a side view of one embodiment of the present invention where radial blades are used as blade support members.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is a reaction turbine capable of unidirectional rotation under reversible fluid flow. Several preferred embodiments are illustrated in the Figures. Other embodiments consistent with the claims are taught by the invention.

In one embodiment, the turbine (10) uses a combination of novel features to extract rotational energy from the kinetic energy of incoming transversal fluid flow (50), deviated transversal flow in a generally axial direction (60) and generally axial flow (65). Referring to Fig. 1, the reaction turbine (10) comprises a rotatable member (12), blade support members (16), substantially twisted turbine blades (18) and substantially radial turbine blades (20).

Rotatable member (12) is engageable to the support member (12A) and defines an axis of rotation (14) about which the turbine (10) rotates in a unidirectional fashion. Support member (12A) may be any structure capable of fixing the position of the rotatable member (12) yet allowing free rotation about the axis of rotation (14). The rotatable member may be any device

capable of smooth rotation. For example, a rotatable hub having bearings (not shown) to allow smooth rotation may be used.

Generally perpendicularly attached to the rotatable member (12) are one or more blade support members (16) which rotate in concert with the rotatable member and in a plane perpendicular to the rotatable member (12). The rotatable member (12) may be coupled, preferably via a gearbox or other torque generating apparatus, to the shaft of a generator (not shown) to convert the turbine's rotational energy into electrical energy or to another device capable of using the power made available by the invention.

Twisted turbine blades (18), preferably but not necessarily having an airfoil cross section (18A), are attached to the blade support members (16) for rotation about the axis of rotation (14). A single blade support member (16) may be used in some embodiments. The cross section of a helical blade (18) has a leading edge (18L) and a trailing edge (18T). The cross sections of the helical blade is oriented so the airfoil profile of the twisted blade (18) is lying in a plane parallel to a component of the transverse fluid flow (50). The changing orientations of the twisted blades cause the the twisted blades to present different faces to the transversal fluid at any given time as they rotate. The twisted blades (18) are designed to generate constant torque from the turbine (10) in a unidirectional direction (70) when the turbine is submerged in a transversal fluid flow (50) irrespective of the angular position of the turbine (10) to the fluid flow.

The design of the twisted blades (18) is accomplished by creating a B-curve (38) on the O-surface (34). The B-curve is monotonous and is defined by angle Ω (32) residing between two tangents. The first is tangent to the B-curve itself and the second is tangent to the O-curve (36) at the point of their intersection. The angle Ω (32) may be constant or change along the length of B-curve (38). B-curve defines the long axis of each twisted blade (18) and a constant angle Ω provides for a cylinder shaped turbine (10). The centers of gravity or pressure of the airfoil

cross sections (18A) of the twisted blades are shown by the B-curve. The cross sections are oriented so their long axes are on the tangents to the circumferences of intersection of the O-surface (40) and the plane perpendicular to the turbine's axis of rotation (14).

The present invention also allows a small angle of attack α (42) between the airfoil cross section's (18A) long axis and the tangent to the circumference. Accordingly, each section of the twisted blade (18) has different shear and rotation forces as compared to a straight blade (not shown) with the same cross section, as illustrated in Figs. 4, 5 and 8.

Referring to Figs. 6 and 7, in one embodiment, the turbine (10) of the present invention contains a number, n, of blades, the number equal to two or more, $n \geq 2$, uniformly distributed, so the turbine (10) has an axial symmetry of n-th order. If the O-surface (34) forms the shape of a cylinder (46), twisted blade air foil geometry and angle Ω are preferred to be constant along the length of the twisted blades (18). In this embodiment, the length to radius ratio is such that $2\Pi/n$ rotation of the turbine places the cross section imprint from one end of the twisted blade (18) on the cross section imprint to the other end, the torque being equal irrespective of the turbine's (10) angular position. In this embodiment, the angle Ω is selected to provide such symmetry or to minimize asymmetry. If other O-surfaces or spheroid or barrel configurations (48) are used the constant torque condition can be approached by varying airfoil cross section (18A) and angle Ω (32) of the twisted blade (18).

In addition to generating torque from the transverse fluid flow (50), the twisted blades (18) cause a portion of the transverse fluid flow (50) to be deviated in a generally axial direction (60) as illustrated in Figs. 2, 3A, 3B, 3C, 4 and 9. The present invention is capable of utilizing deviated generally axial flow (60) or any axial flow to increase rotational energy and the overall efficiency of the turbine (10). This is accomplished by substantially radial blades (20) attached to the twisted blades (18). These radial blades (20) are preferably substantially perpendicular to

the turbine's axis of rotation (14) and are capable of converting a portion of the kinetic energy of the fluid flowing in a generally coaxial direction (60, 65), whether deviated by the twisted blades (18) or not, into rotational energy.

Referring to Figs. 2 and 3, The radial blades (20) of the present invention are equipped with air foil cross sections (20A) having a leading edge (20L) and a trailing edge (20T) to produce more rotational energy than if the radial blades (20) were flat. The airfoil cross sections (20A) of the radial blades (20) may be symmetrical (teardrop shaped) or asymmetrical. In one embodiment of the present invention, the leading edge (20L) of the radial blades face in the same direction as the leading edge (18L) of the twisted blades (18). The radial blades (20) may or may not protrude from either or both the inner (80) and outer surfaces (90) of the twisted blades (18) and may be distributed uniformly or non-uniformly along the twisted blades (18). The preferred distribution of the radial blades (20) is contingent upon the twist angle, as described below, and the relative size of the twisted blades (18).

The deviated flow in a generally axial direction (60) created by the twisted blades (18) also causes a first axial force in a first direction to act upon the rotatable members (12). The radial blades (20) may be designed with an asymmetrical cross section to create a second axial force in a second opposed direction. This feature of the present invention may be useful for maintaining the resiliency of turbine bearings (not shown) when the rotatable member (12) used is a hub having such bearings.

In one embodiment of the present invention, the blade support members (16) are extended radial blades (20). The present invention allows the benefits of the radial blades to be distributed along both ends of the turbine (10) by using elongated radial blades (20) to connect the twisted blades (18) to the rotatable member (12). These radial members can provide both support for the twisted blades (18) and also increase the efficiency of the turbine (10) by converting a portion

of the kinetic energy of the fluid flowing in a generally coaxial direction (60, 65), whether deviated by the twisted blades (18) or not, into rotational energy.

In one embodiment of the present invention, uniformity of rotation is achieved by providing for variable size of the twisted blade cross section (18A). The cross section of the twisted blades may be increased for cross sections proximate to the rotation axis of the turbine. A larger cross sectional thickness may be used for those sections of the twisted blades (18) that are closer to the axis of rotation (14). The pulling forces of the twisted blades (18) are increased because of an increase in the cross sectional area, thus compensating for a smaller linear speed and distance to the axis, which typically leads to a smaller torque. This embodiment of the present invention allows the torque generated to be independent from the angular position of the turbine (10). This innovation is particularly useful where the twisted blades (18) of the turbine (10) are curved and particularly for turbines (10) where the twisted blades (18) cause the turbine to have a barrel-shaped orientation.

Referring to Figs 6 and 7, by rotating a plane curve, referred to herein as an O-curve (36) with respect to the axis of rotation (14) lying in the same plane, an O-surface (34) may be obtained having an axial symmetry. The O-surface defines the overall shape and dimension of the turbine (10). The design of the present invention allows several shapes and dimensions of the turbine (10). For example, a small O-curve curvature would lead to a barrel shaped turbine (44), a straight line parallel to the axis of rotation would lead to a cylinder shaped turbine (46) and an O-curve that intersects the axis of rotation (14) would create an ellipsoid or spherical shaped turbine (48).

The ability of the turbine (10) of the present invention to make use of both transversal (50) and generally axial flow (60, 65) results in a greater overall efficiency of the turbine (10) than turbines without the advantages of the invention turbine. The higher the Ω angle or twist

angle (32), the more deviation of transversal flow is obtained. Therefore, a turbine (10) of the present invention may have a higher angle Ω (32) for the twisted blades (18) due to the ability of the radial blades (20) to make use the deviated transverse flow in a generally axial direction (60). For example, in one embodiment, the angle Ω (32) may be larger than the optimal one (approximately 32°) for the helical blades of the Gorlov turbine described above. Additionally, the invented radial blades allow the turbine to be more compact than a conventional Gorlov turbine while delivering the same rotational energy. The present invention allows the same efficiency of the Gorlov turbine but allows a smaller length to diameter ratio.

Referring to Figure 9, a ring shaped zone of deviated transversal flow in a generally axial direction (60) is illustrated. This deviated axial flow is caused by angle Ω at which the twisted blades engage the transverse flow (50).

The radial blades are preferably spaced far enough apart from each other on the twisted blades so they do not interfere with the fluid flow to each other. Depending on the size and the shape of the radial blades and the twist of the twisted blades, an optimal number of blades may be optimally arranged and spaced on each twisted blade. Optimal spacing and arrangement of radial blades requires knowledge of the directions and type of fluid flow the turbine will be expected to experience.

If the curve of the radial blade facing an actual fluid flow is appropriate, general axial fluid flows, even an axial fluid flow which is parallel with the rotation axis of the axial turbine, may generate rotational energy from its interaction with the radial blades. Further, an originally transversely moving fluid which is deviated by the twisted blade and travels "down" the slope of the twisted blade contains both an axial force component and an transverse force component. The radial blade is sized and positioned on the twisted blade to be capable of converting a portion of the transverse force component into rotational energy. Thus, the radial blades make the

turbine both more efficient in converting transverse fluid flow through the turbine into rotational energy and also more effective at converting fluid flow through the turbine at other angles.

The radial blades may be sized and positioned into rotational energy with geometries and distances ranging from fish like radial blades of approximately one centimeter in height and spaced approximately one centimeter apart to much larger radial blades, to as few as two radial blades on a given twisted blade. It is not necessary for there to be radial blades on each twisted blade or for the configuration or arrangement of the radial blades on each twisted blade to be the same on all the twisted blades in a turbine as long rotational imbalance does not occur. It is preferable, however, for the number of blades on each twisted blade to be equal to two or more and to be uniformly distributed so the turbine has an axial symmetry of the n-th order. For balance, the radial blades must be fixed to more than one twisted blade.

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention that may be embodied in various and alternative forms. The figures are not necessarily to scale, some features may be exaggerated or minimized to show details of the particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention.

Furthermore, elements may be recited as being "coupled"; this terminology's use contemplates elements being connected together in such a way that there may be other components interstitially located between the specified elements, and that the elements so specified may be connected in fixed or movable relation one to the other. The term "coupled" should be contrasted with the use of the terminology "direct" connection which designates a relationship or joinder that does not have other components interstitially located there between,

but the components may be fixed or movable with respect to one another. Still further, some structural relationships or orientations may be designated with the word "substantially". In those cases, it is meant that the relationship or orientation is as described, with allowances for variations that do not affect the cooperation of the described component or components.

Although the invention has been described with reference to a specific embodiment, this description is not meant to be construed in a limiting sense. On the contrary, various modifications of the disclosed embodiments will become apparent to those skilled in the art upon reference to the description of the invention. It is therefore contemplated that the appended claims will cover such modifications, alternatives, and equivalents that fall within the true spirit and scope of the invention.

PATENT CLAIMS

I claim:

1. A reaction turbine, for mounting to a support member, capable of unidirectional rotation under reversible fluid flow comprising:

a rotatable member engageable to said support member, said rotatable member defining an axis of rotation for said turbine;

a plurality of blade support members generally perpendicularly attached to said rotatable member for rotation therewith in a plane generally perpendicular to said rotatable member;

a plurality of substantially twisted turbine blades attached to said blade support member for rotation about said axis of rotation, a plurality of said twisted blades having an airfoil cross section and having a leading edge and a trailing edge and an airfoil profile lying in a plane generally parallel to a component of said fluid flow;

a plurality of substantially radial turbine blades attached to a plurality of said twisted blades, said radial blades being substantially perpendicular to said axis of rotation and capable of converting a portion of the kinetic energy of said fluid flowing in a generally axial direction into rotational energy, thus increasing the efficiency of said turbine, said radial blades having an airfoil cross section to produce more rotational energy than if said radial blades were flat;

said reaction turbine with said radial blades being capable of converting more energy from said fluid flow into rotational energy than a similar reaction turbine without said radial blades.

2. The turbine of claim 1, wherein said airfoil cross section of said radial blades is symmetrical.

3. The turbine of claim 1 wherein a plurality of said radial blades have a leading edge and a trailing edge, said leading edge facing in the same direction as said leading edge of said twisted blades.

4. The turbine of claim 1, wherein a plurality of said blade support members comprise radial blades, said radial blades/blade support members connecting said twisted blades to said rotatable member, said radial blades/blade support members providing both support for said twisted blades and increased efficiency of said turbine than a similar turbine without radial blades.

5. The turbine of claim 1, wherein said cross section of said twisted blades is increased for at least some cross sections proximate to said rotational axis of the turbine.

6. The turbine of claim 1 wherein said twisted blades have a higher twist angle and the turbine has a smaller length to diameter ratio than a similar turbine without said radial blades which is capable of producing an equivalent amount of rotational energy from an equivalent fluid flow.

7. The turbine of claim 1 wherein the angle of attack alpha between the twisted blade's long axis and the tangent to the turbine's circumference is smaller than that of a similar turbine without said radial blades which is capable of producing equivalent rotational energy from said fluid flow.

9. A reaction turbine for mounting to a support member capable of unidirectional rotation under reversible fluid flow comprising:

a rotatable member engageable to said support member, said rotatable member defining an axis of rotation for said turbine;

a plurality of blade support members perpendicularly attached to said rotatable member for rotation therewith in a plane perpendicular to said rotatable member;

a plurality of substantially twisted turbine blades attached to said blade support member for rotation about said axis of rotation, a plurality of said twisted blades having an airfoil cross section and having a leading edge and a trailing edge and an airfoil profile lying in a plane parallel to a component of said fluid flow; said twisted blades having a higher twist angle and the turbine has a smaller length to diameter ratio than a similar turbine without said radial blades which is capable of producing an equivalent amount of rotational energy from an equivalent fluid flow;

a plurality of substantially radial turbine blades attached to said helical blades, a plurality of said radial blades having a leading edge and a trailing edge, said leading edge facing in the same direction as said leading edge of said twisted blades, said radial blades capable of converting a portion of the kinetic energy of said fluid flowing in a generally axial direction into rotational energy, thus increasing the efficiency of said turbine, said radial blades having an airfoil cross section to produce more rotational energy than if said radial blades were flat;

at least some of said blade support members comprising radial blades, said radial blades connecting said twisted blades to said rotatable member, said radial blades providing both support for said twisted blades and increased efficiency of said turbine;

said reaction turbine with said radial blades with airfoil cross sections being capable of converting more energy from said fluid flow into rotational energy than a similar reaction turbine without said radial blades with airfoil cross sections.

8. The turbine of claim 1 wherein the turbine contains a number, n, of radial blades, the number equal to two or more, uniformly distributed so the turbine has an axial symmetry of the n-th order.

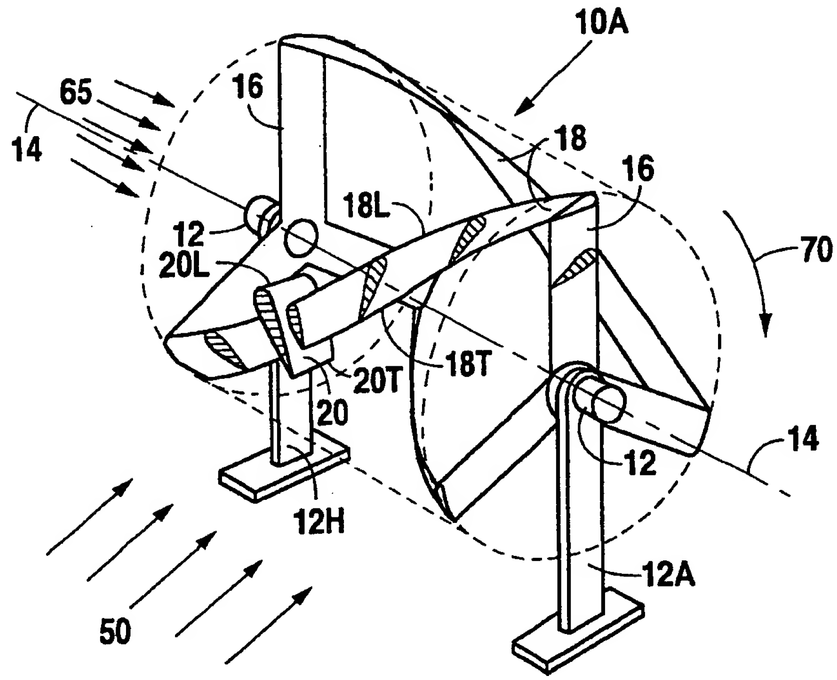
10A
65
16
14
18
16
18L
12
70
20L
18T
20T
20
14
12
12H
12A
50

Fig. 1

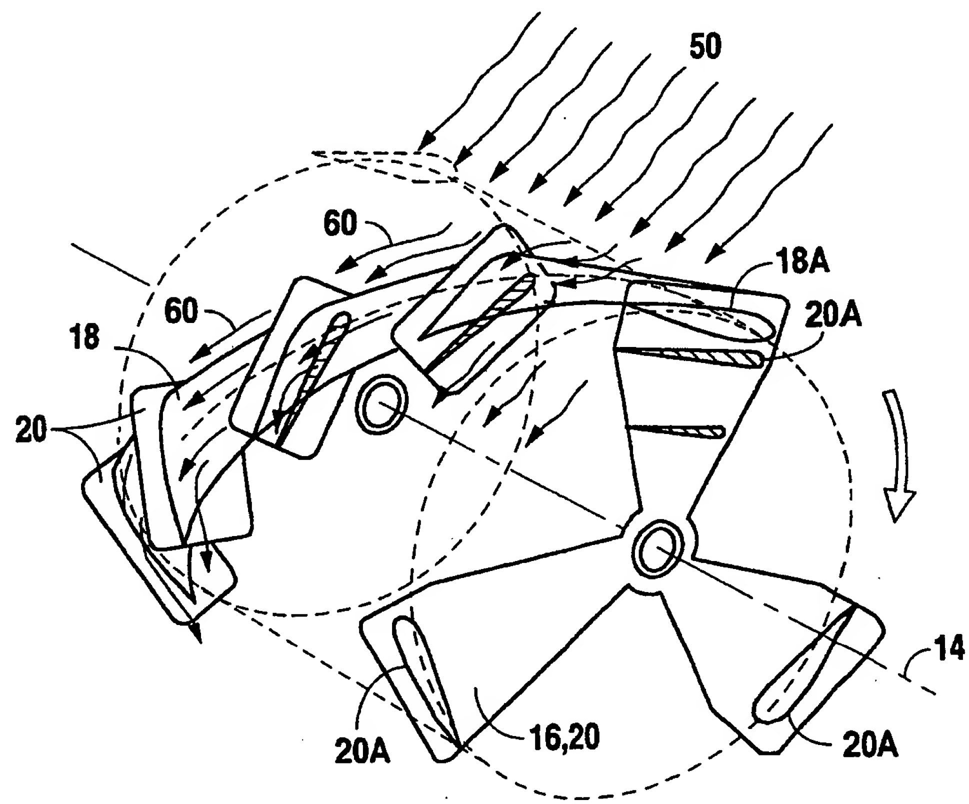
50
60
18A
60
20A
18
20
14
20A
16,20
20A

Fig. 2

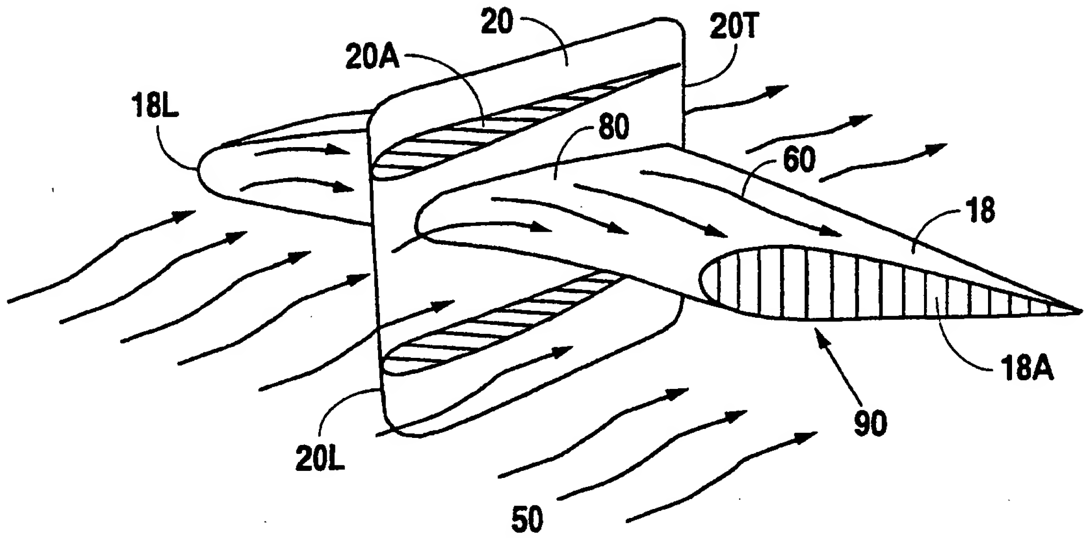

Fig. 3A

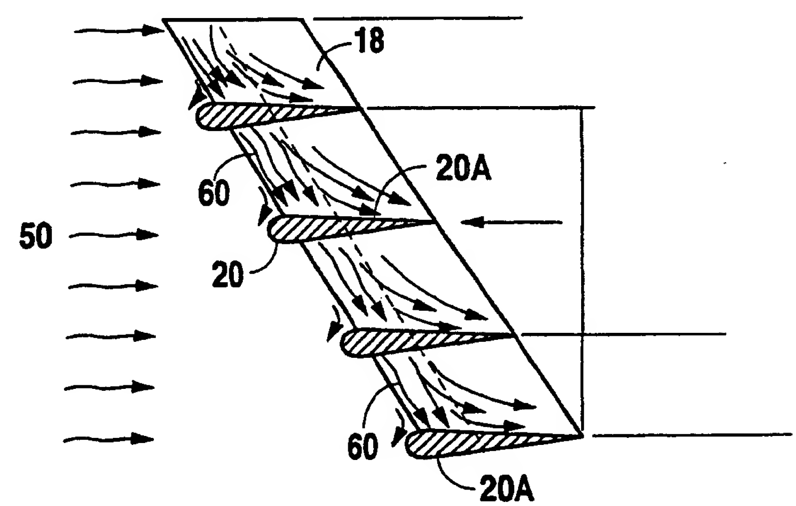

Fig. 3B

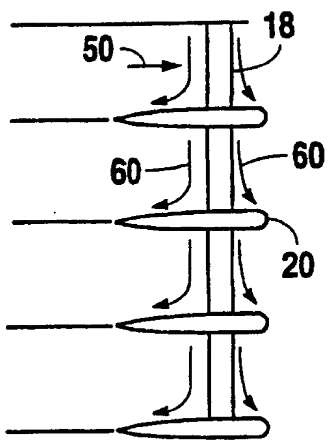

Fig. 3C

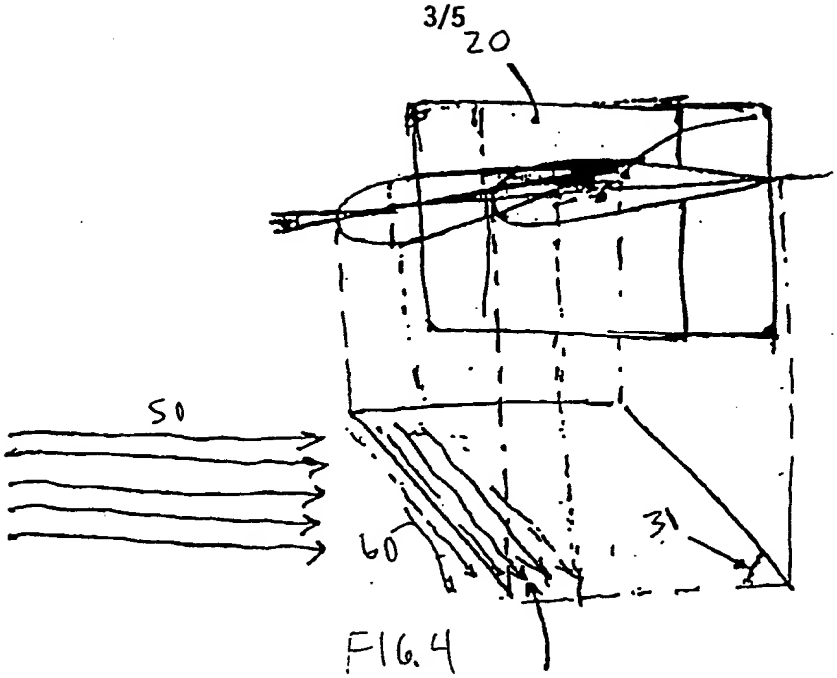

FIG. 4

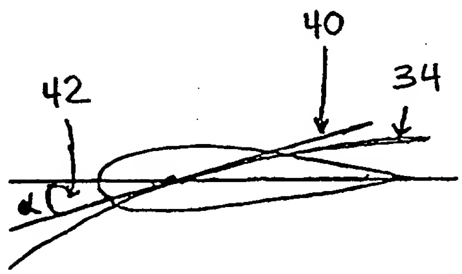

Fig. 5

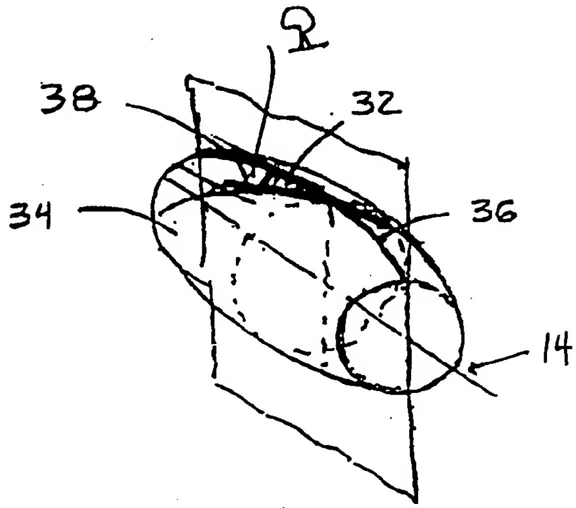

Fig. 6

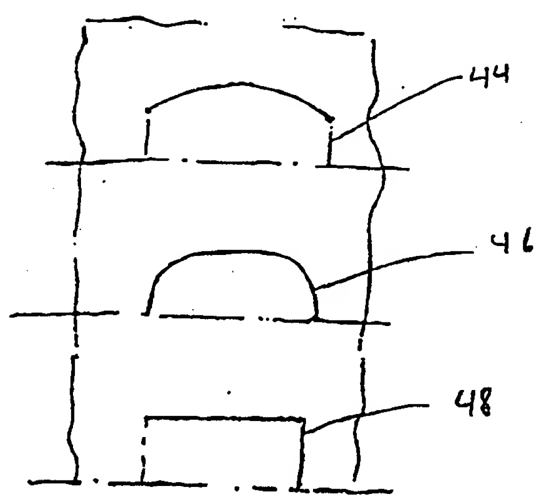

Fig. 7

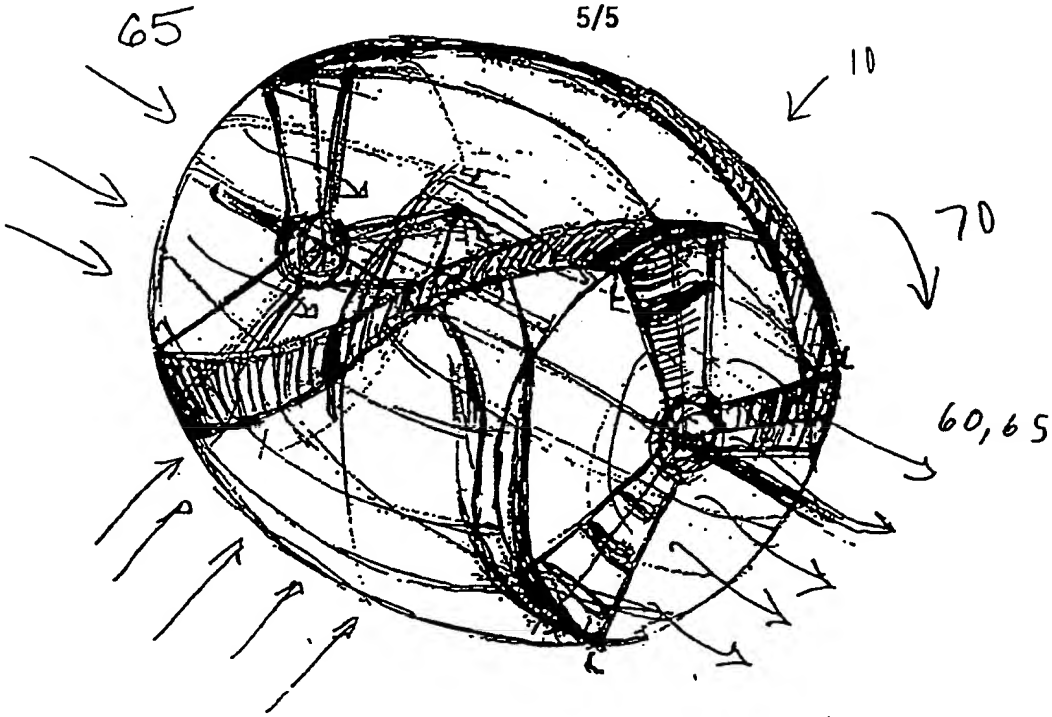

Fig. 8

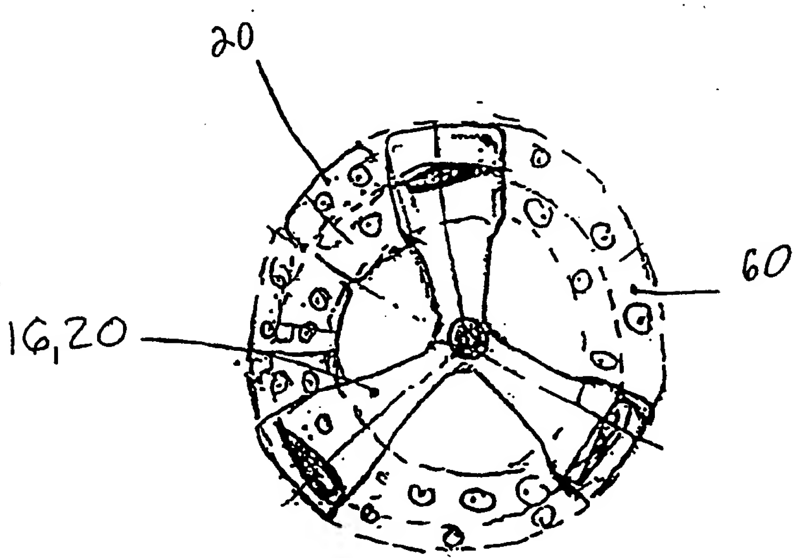

Fig. 9